Development of Road Traffic Noise Prediction Model in Urban Perspective

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Abstract— India is one of the fastest growing countries all over the world. The development of road is considered the backbone of any developing country like India. The Construction of highway network in a country leads to modernisation, urbanisation and industrialisation. The number of vehicles is increasing with the expansion of highway network. With the increase in number of vehicles the road traffic noise is also increasing day by day. Road traffic noise seems to be the biggest corridor problem and the most intrusive and annoying form of noise pollution. Therefore it has become necessary to reduce the traffic noise. Many authorities have shown their concern in this regard. The aim of the study is to develop a scale model to predict noise level in urban areas. The developed formula may be used to predict pseudo noise levels and may be used to reduce traffic noise. In the present study 25 road segments of Bhopal city were considered and readings were taken for one hour twice in a day i.e., morning and evening. Based on the analysis the developed model is having coefficient of determination value (R^2), 0.766.

Key words: Traffic, Noise Pollution, Modernisation, Prediction Models

I. INTRODUCTION

Environment is defined as sum total of biotic and abiotic things and their mutual relationship with each other. Major current environmental issues include air pollution, water pollution, soil pollution and noise pollution. Out of above-mentioned problems, the least considered and unattended issue is noise problem and is largely neglected by most of engineers, planners, and politician worldwide. Unlike other pollution like air pollution, water pollution, and soil pollution, noise pollution is distinct because noise pollution does not have any residual evidence that would serve as a continuing remainder of its unpleasantness. Noise pollution is unattended issue in India but in European Union noise problems are concerned at the highest level together with major issues like global warming [1]. India is a developing country and length of highway network is one of the indicators of development of any country. Indian highway networks consist more than 4.32 million kilometres of road, which is the second largest highway network in the world. Highway network in India consists 65% freight traffic and rest are passenger traffic [2]. Number of vehicles on Indian roads is increasing day by day which leads to increase in traffic noise which is affecting human health [3, 4]. Noise exposure at night is creating a number of secondary effects like psychological and physiological symptoms which in turn lessens the working efficiency of adult [5]. Ohrstrom and Skanberg [6] carried out a detailed study about the consequences of traffic noise on sleep disturbance in which they found that quality of sleep was reduced up to 22% and 20.5% in laboratory and home respectively after comparing between sleep at traffic noise exposure and sleep at quiet reference night. Noise exposure during night may also lead to disturbance in sleep cycle stages[7] and also slow wave sleep is greatly reduced due to noise exposure at night while the rhythm of Rapid Eye Movement sleep gets affected by it[8,9]. It is better to adopt preventive measures for traffic noise problems before facing any major consequences associated with it. Since it is not possible to measure traffic noise in the designing stage, traffic noise prediction model may be a useful tool to predict the pseudo traffic noise level at planning stage. While planning of new highway networks, traffic noise prediction model may found to be useful in order to provide pleasant living atmosphere in residential, silence, commercial and industrial areas. Moreover, traffic noise models may help in planning eco-friendly roads [10]. Generally, a large number of variations are found in sound pressure levels. When response of human ears are considered to different sound levels, A- weight sound filter is found to be best suited among different weighing filters and is measured in terms of decibel (dB) [11]. In India, there is lack of research in this field. Thus there is need to develop road traffic noise prediction model by considering the increase in daily traffic due to rapid urbanizations. Therefore this study presents development of road traffic noise prediction model for heterogeneous traffic conditions in Indian cities. This paper consists of four sections, first section presents the general introduction of traffic noise, the problem associated with it and traffic noise prediction model. Second section discusses the data collection, procedure and methodology for development of model. Third section presents the analysis work carried out in the study. The last section presents the important conclusion drawn from the study.

II. DATA COLLECTION AND METHODOLOGY

This section presents details of road stretch in which characteristics of selected road stretch have been discussed. It also presents procedure to collect noise data, spot speed data and vehicular count data.

A. *Details of Road Stretch*

All the data were collected twice for every stretch i.e. morning and evening peak hour duration. To cover the variation of drivers and vehicles behaviour which depends upon the travel direction, measurements were taken on either sides of road for peak hour traffic during morning and evening. Total 25 locations were selected having 4 lanes divided carriageway. During peak hour, readings were taken on both sides i.e. 20 minutes on each sides and 10 minute time was elapsed during shifting of instrument in between the two observations.

B. Data Collection

Details of instruments used for sound pressure level measurement and spot speed measurement have been discussed briefly in this section. It also presents the standard format of traffic count measurement used in the present study.

1) Sound Pressure Level Measurement

Recording of sound pressure level is done with the help of digital sound level meter model: SoundPro SP DL-2.This instrument was developed by Quest Technologies. The essential features of this instrument are it can record A, C and Z weightage sound level. This instrument has speciality of sound level monitoring and comprehensive data analysis. The instrument was on during the survey which used to record sound level and data was stored in micro SD card, later data can be extracted from the instrument. While recording the steps which were followed to get accurate sound pressure level are instrument is calibrated each time before the recording using standard calibrator provided by the company.

2) Spot Speed Measurement

Radar gun was used to detect the spot speed of each class of vehicle travelling in the survey direction. Digital data obtained from radar gun were recorded manually in a prescribed format. For each categories of vehicles, the maximum possible number of spot speed readings were made.

3) Traffic Volume count

On the basis of standard format of IRC SP 19 (Indian Roads Congress) number of vehicles crossing the survey sections along the path of measurement and in opposite path were determined manually. The general composition of traffic in the study area was two wheelers, three wheelers, four wheelers (vans/jeeps/cars), trucks and buses.

C. Methodology

This section presents the methodology used in the present study. Figure 1 presents methodological flow chart of present work.

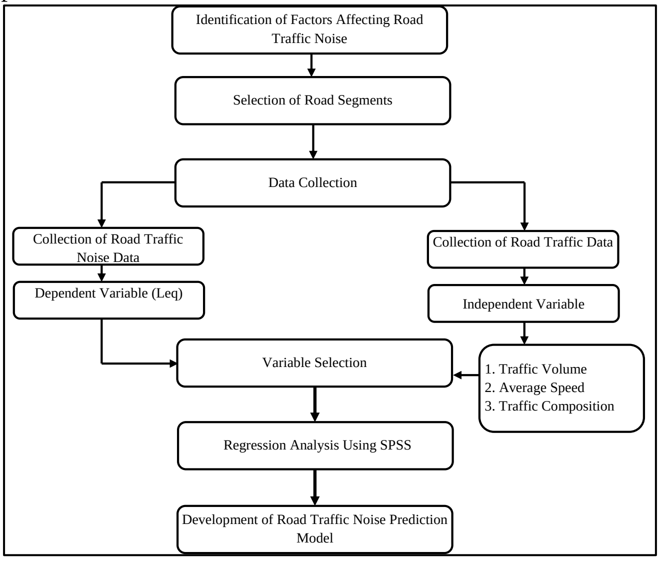

Fig. 1: Methodology for Development of Road Traffic Noise Prediction Model

III. ANALYSIS AND RESULT

This section presents inter-correlation matrix, model development, model validation and scatter plots. In this section detailed analyses have been carried out on the basis of data collected and these are discussed along with the results obtained.

A. Inter-correlation Matrix of Parameters

Using the observed data, a correlation study is performed and based on the results of correlation study, correlation matrix is formed and presented in table 1.1.

Parameters	Leq	V	Q	PB	PT	PO
Leq	1	.473	.493	.469	.475	.25
V	.473	1	.444	.349	.448	-.025
Q	.493	.444	1	.457	.478	-.052
PB	.469	.349	.457	1	.458	.011
PT	.475	.448	.478	.458	1	-.171
PO	.025	-.025	-.052	.011	-.171	1

Table 1: Inter-Correlation Matrix

B. Model for Prediction of an Equivalent Noise Level

A total 50 set of data is used to develop the model. Analysis was done using the software SPSS and a proper model is developed which may be used to predict traffic noise in four lane divided carriageway. Subset method is used to develop the final expression.

No. of Variables	Set of independent variables	R^2	F
2	Leq+Q	.480	49.775
	Leq+V	.453	44.714
	Leq+PB	.448	43.803
	Leq+PT	.456	45.176
	Leq+PF	.040	00.023
	Leq+PH	.293	22.350
	Leq+PO	.001	00.035
3	Leq+Q+V	0.646	48.390
	Leq+Q+PB	0.596	39.143
	Leq+Q+PT	0.624	43.922
	Leq+Q+PF	0.324	18.643
	Leq+Q+PH	0.543	31.445
	Leq+Q+PO	0.483	24.796
4	Leq+Q+V+PB	0.729	46.716
	Leq+Q+V+PT	0.699	40.193
	Leq+Q+V+PF	0.681	36.989
	Leq+Q+V+PH	0.652	32.425
	Leq+Q+V+PO	0.650	32.192
5	Leq+Q+V+PB+PT	0.760	40.299
	Leq+Q+V+PB+PF	0.759	40.095
	Leq+Q+V+PB+PH	0.735	35.291
	Leq+Q+V+PB+PO	0.732	34.772
6	Leq+Q+V+PB+PT+PO	0.766	32.700
	Leq+Q+V+PB+PT+PH	0.760	31.679
	Leq+Q+V+PB+PT+PF	0.762	31.962

Table 2: Subset Analysis

Equivalent level of noise in dB(A) expressed as equation 1.1,

$$Leq = 33.739+.208V+.001Q+0.164PB+.313PT+.844PO \quad (1.1)$$

Where Leq is A-weighted sound pressure level in dB,
V is speed of section in km/hr,
Q is traffic volume,
PO is percentage of other vehicles,

PT is percentage of three wheelers.
PB is percentage of two wheelers,
33.739 is a regression constant

C. Model Validation

A different route is selected for model validation, 8 set of data is collected from this route. The independent data is put up in the model to calculate the pseudo sound pressure level. After calculating predicted data, a comparison has been made with observed noise level and it was found that correlation between them was 0.884. The performance of the model has been tested using standard error, mean multiplicative error and correlation coefficient.

The standard error has been determined using the following equation: -

$$SE = [\sum_{i=1}^{N} \frac{(K_p - K_m)^2}{N}]^{\frac{1}{2}} \quad (1.2)$$

The mean multiplicative error (MME) is considered to provide a better basis for assessing the impact of inaccuracies in predicting the variable.

$$MME = e^{[\sum_{i=1}^{N} \frac{\ln(K_p/K_m)}{N}]} \quad (1.3)$$

Where, K_P is predicted values and K_m is measured values.

We will take observed values of Leq for the surveyed sections; also use the model equation for finding the predicted value of Leq for the same location. Figure 2 shows relation the predicted and observed values.

Standard value for SPL was found 0.2422 for the studied sections, and where the MME value calculated using above formula was found to be 0.1259

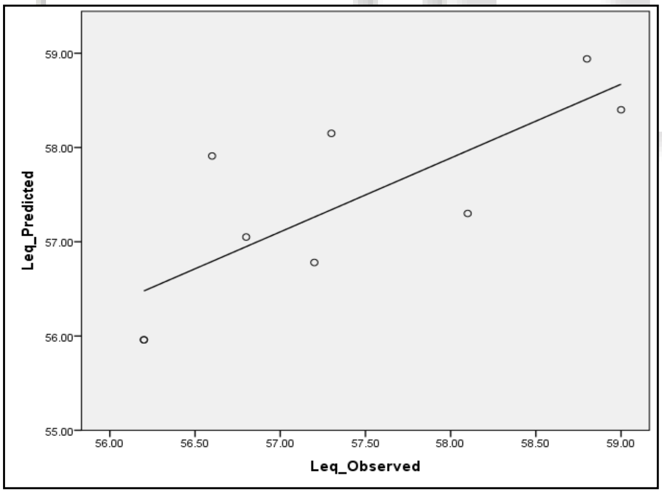

Fig. 2: Graph between observed and predicted equivalent sound pressure level

D. Scatter Plot

Scatter plots of V Vs Leq, Q Vs Leq, PB Vs Leq, PT Vs Leq, PF Vs Leq, PH Vs Leq and PO vs Leq are plotted to examine a possible relationship between individual parameters on an equivalent level of noise.

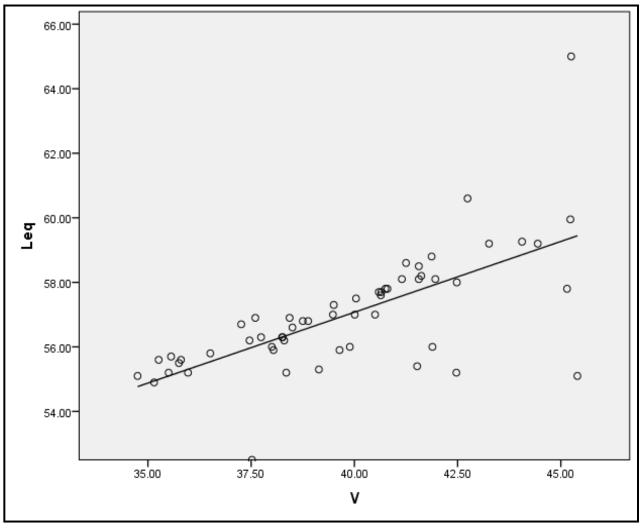

Fig. 3: Spot Speed of Vehicles (V) in regard to equivalent noise level (Leq)

Figure 3 shows that the equivalent sound pressure level increases with an increase in spot speed of vehicles. Hence, it is proven that the spot speed of vehicles increases the equivalent noise level. Thus, the increase in spot speed of all kinds of vehicles increases the equivalent sound pressure level.

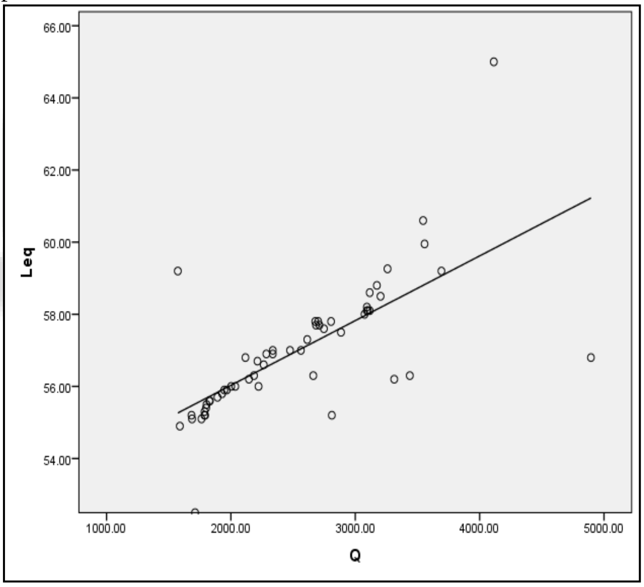

Fig. 4: Total traffic volume (Q) in regard to equivalent noise level (Leq)

Figure 4 presents that the equivalent sound pressure level increases with total traffic volume. Hence, it is proven that total traffic volume increases the equivalent noise level.

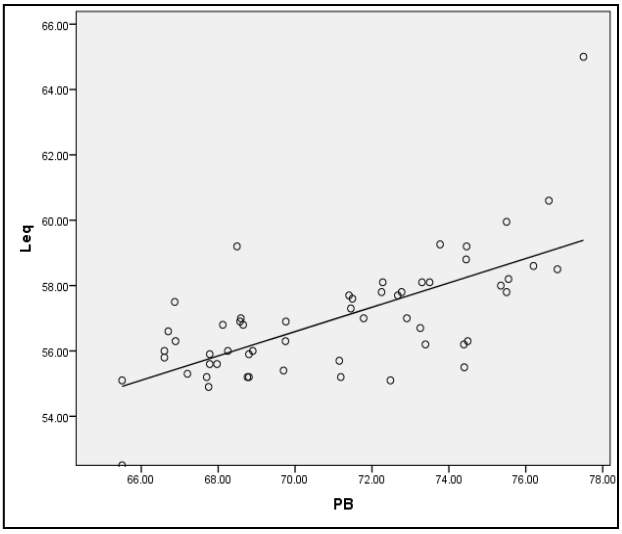

Fig. 5: Percentage of two wheelers (PB) in regard to equivalent sound pressure level (Leq)

Figure 5 shows that the equivalent sound pressure level increases with percentage of two wheelers. Hence, it is proven that percentage of two wheelers increases the equivalent noise level.

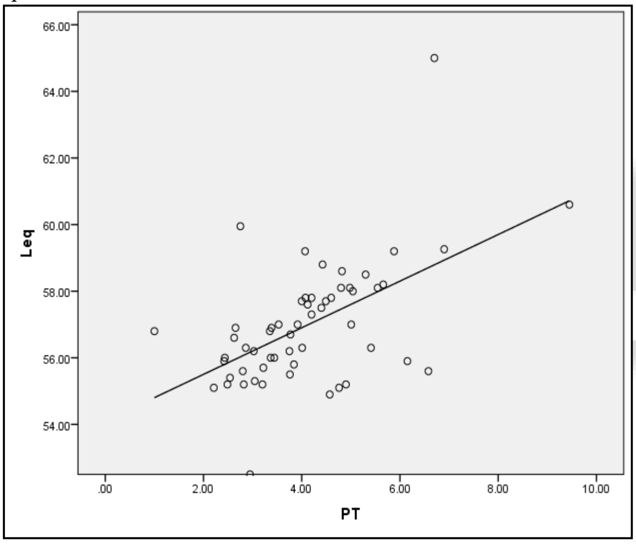

Fig. 6: Percentage of three wheelers (PT) in regard to equivalent noise level (Leq)

Figure 6 shows that the equivalent sound pressure level increases with percentage of three wheelers. Hence, it is proven that percentage of three wheelers increases the equivalent noise level.

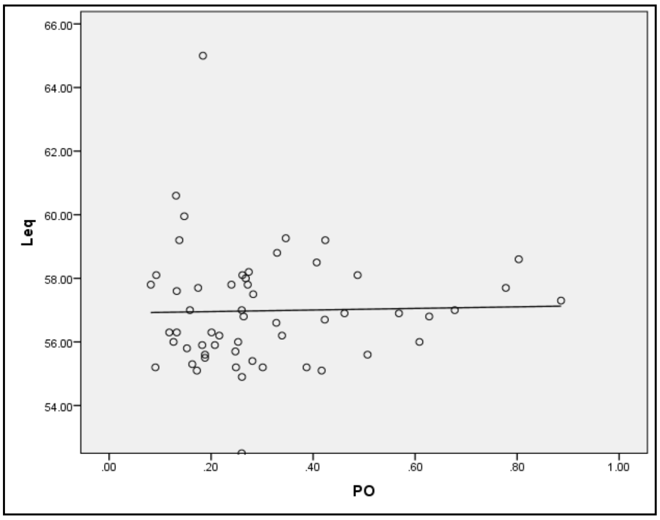

Fig. 7: Total traffic volume (Q) in regard to equivalent noise level (Leq)

Figure 7 shows that Percentage of other vehicles does not affect much on equivalent sound pressure level.

IV. CONCLUSIONS

Based on the data collected from four-lane divided carriageway having uninterrupted traffic flow condition, a model for predicting the equivalent sound pressure level was developed using the SPSS software. Its goodness of fit was also investigated to check the level of its suitability. The following conclusions were drawn on the basis of this study. The multiple linear regression equation for predicting the equivalent sound pressure level (Leq) was established using the following parameters: the total number of vehicles (Q), percentage of two wheelers (PB), spot speed of vehicles (V), percentage of three wheelers (PT), and percentage of other vehicles. Standard error and mean multiplicative error for observed and predicted sound pressure level were also negligible.

1) Correlation study reveals that total traffic volume, speed of vehicle, percentage of two wheeler, percentage of three wheeler, and percentage of other vehicle affects road traffic noise.
2) The value of R^2 obtained by Multiple Linear Regression Analysis lies in between 0.7 to 1.0 for the equation of Leq. R^2 value for the final equation of Leq is 0.766. If the value of R^2 lies in the range of 0.7 to 1 then it indicates very good correlation between observed and predicted data sets. Further enhancement of R^2 can be done by increasing the number of data and taking different site location to cover wide range of variations.
3) The paired t- test was also carried out to provide the statistical test for the differences between the predicted results from the model and the measured result from the field. The null hypothesis was zero, that is the mean value of the differences between pairs of measured Noise and predicted Noise is equal to zero. The results from paired t- test at a significance level of 5 % show that the critical value is greater than t–statistics, so the null hypothesis is accepted, that is the mean value of difference between measured and predicted Noise level is zero.

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